

(19)



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(11)

**EP 0 830 032 B1**

(12)

## EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention  
of the grant of the patent:  
**20.03.2002 Bulletin 2002/12**

(51) Int Cl.7: **H04N 9/31**

(21) Application number: **97119243.0**

(22) Date of filing: **17.12.1992**

(54) **White light enhanced colour field sequential projection system**

Farbprojektionssystem mit sequentieller Rasterfolge und verbesserter Helligkeit

Système de projection couleur à séquences de trames avec luminosité améliorée

(84) Designated Contracting States:  
**DE FR GB IT NL**

(30) Priority: **18.12.1991 US 809816**

(43) Date of publication of application:  
**18.03.1998 Bulletin 1998/12**

(62) Document number(s) of the earlier application(s) in  
accordance with Art. 76 EPC:  
**92121490.4 / 0 547 603**

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**EP-A- 0 114 553** **EP-A- 0 268 706**  
**EP-A- 0 330 361** **EP-A- 0 391 529**  
**WO-A-83/03038**

- **PATENT ABSTRACTS OF JAPAN vol. 11, no. 374 (E-562), 5 December 1987 & JP 62 141854 A (FUJI PHOTO FILM CO LTD)**
- **PATENT ABSTRACTS OF JAPAN vol. 15, no. 304 (E-1096), 5 August 1991 & JP 03 108982 A (FUJITSU GENERAL LIMITED), 9 May 1991**
- **PATENT ABSTRACTS OF JAPAN vol. 15, no. 401 (E-1121), 11 October 1991 & JP 03 163985 A (PIONEER)**

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**EP 0 830 032 B1**

**Description****1. Field of the Invention**

**[0001]** This invention relates to color projection systems, more particularly to video display systems that use a white light source.

**2. Background of the Invention**

**[0002]** The use of white light sources in color projection systems offer many advantages. They are relatively inexpensive, use low amounts of power, and are easier to install and replace. Other options, such as lasers, or Light-Emitting Diodes (LEDs), are expensive, use large amounts of power and require three sources, one for red, green, and blue, respectively.

**[0003]** White light also offers the full color spectrum, which can be filtered to select a desired color, such as red, green and blue. This becomes important when the light is to be directed to the projection surface, as is done when spatial light modulators are used. Normally, the spatial light modulator is positioned between the source or sources, and the projection surface, be it a television, a printer drum, a piece of photographic film, or any photosensitive media. The light from the source impinges upon the modulator that, in turn, selectively directs the light to the projection surface. In this type of system, the color of the light is normally done with filters.

**[0004]** The color filtering can be done either spatially or temporally. In order to spatially color filter, three sets of arrays, or three sections, such as rows on one array, could be filtered for one of the three required colors. The key in this instance is to separate the colors and direct one color onto its own dedicated space, such as a separate modulator device, or an area upon one device.

**[0005]** The other option is to temporally filter the light. One way is to use a rotating filter that is divided into equal fields of the three colors. This is normally called a color wheel. The standard wheel is divided into three arcs of the circle, each being 120°. The wheel then spins in front of the source, relaying the appropriate amount of each color to the projection surface. The amount of each color is dependent on how long the cells of the modulator pass the colored light to the surface.

**[0006]** An inherent trade-off exists in any color projection system. If the desire is for color saturation, there will be a drop-off in overall brightness. Likewise, if overall brightness is desired, some loss in color saturation will possibly result. In many cases, viewers have been found to favor brightness over color saturation. A problem exists in standard color projection techniques, which tend to favor color saturation over brightness. Therefore, a way is needed to adapt the current methods of color projection to provide better brightness, without having too great an effect upon color saturation.

**[0007]** The initial solution to this problem would be to simply use a brighter light. Depending on the system limitations and requirements, it may not be possible to use a bright enough source to alleviate this problem. Therefore, some alternate solution must be found.

**[0008]** In this connection, reference is made to EP-A-0 268 706, which discloses an apparatus for improving the perceptibility of details on a hard-copy of a color image and for matching the color of a displayed image and a color hard-copy of the same image. A color recording material is exposed to color separations of said image. In particular, video signals representing the red, green and blue primary color separations are in sequence applied to a monitor in order to display the corresponding partial images. The color information on a color recording material is obtained by projecting the displayed red, green and blue color separation images through a corresponding color filter. The perceptibility of details is improved by additionally exposing the recording material to at least one white light exposure, wherein the white light exposure is modulated by the information of at least one of the color separations, by projecting the corresponding displayed image(s) through a neutral or through no filter.

**[0009]** From Patent Abstracts of Japan and JP-A-3108982, a projection type video display device is known, in which energy consumption is reduced and the life of the device is prolonged by adding a cathode ray tube exclusive for white color. Input red, green and blue video signals are respectively supplied to operational amplifiers and to a minimum level signal detection circuit. In the minimum level signal detection circuit, a video signal at the minimum level selected out of the video signals is supplied through a picture output circuit to a white high luminance cathode ray tube as the white video signal component of the red, green and blue video signals. Then, the white picture is reproduced. On the other hand, in the operational amplifiers, a video signal at the minimum level attenuated by an attenuator is subjected from the respective input red, green and blue video signals, output and supplied to respective single color high luminance cathode ray tubes.

**[0010]** From WO-A-83/03038, it is known to direct the light from one white light source into four separate projection paths using mirrors and dichroic beam splitters. The light is used to illuminate images which are stored in the form of analog, digital or figure-like image signals on a coated or transparent synthetic band sheet in four separate tracks, one for each of the primary colors red, green and blue and one for black and white. The transmitted or reflected light from

the band sheet is projected onto a CCD array and the red, green and blue signals of color television and the black and white signals of black and white television are derived therefrom by means of an electronic converter.

### Summary of the Invention

[0011] The video display system disclosed herein comprises enhancing color projection systems with the use of white light. A portion of the original white light beam is preserved to raise the overall brightness of the scene. The filtered beams of red, green and blue are used to color the scene to the appropriate extent. The original white light beam can be filtered either spatially or temporally, with either a portion of time or illuminated surface area being reserved for white light. A controller determines the minimum brightness to be reached by the white light.

[0012] According to one aspect of the present invention there is provided a video display system having the features defined in claim 1.

[0013] According to a second aspect of the present invention there is provided a video display system having the features defined in claim 4.

### Brief Description of the Drawings

[0014] For a more complete understanding of the present invention and for further advantages thereof, reference is now made to the following Detailed Description taken in conjunction with the accompanying Drawings in which:

[0015] Figures 1A-1C show a standard color wheel, and adaptations to utilize white light.

[0016] Figures 2A and 2B show one embodiment for spatially filtering color, and an adaptation to utilize white light.

[0017] Figures 3A and 3B show an alternative embodiment for spatially filtering color, and an adaptation to utilize white light.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Temporal color filtering is normally done by allocating a certain time segment to each of the three primary additive colors, where the segments are equal. There are many techniques for temporal filtering, one of which is a color wheel. For discussion purposes, the concepts of temporal filtering using white light will be discussed in the context of the color wheel.

[0019] A three-color wheel is shown in Figure 1A. The wheel is divided evenly into three colors, red 10, green 12, and blue 14. The color wheel rotates once a video frame or field, depending upon the scanning mode in use. When the normal frame rate is 60 frames/sec, the color wheel rotates 60 times a second, or 3600 revolutions per minute.

[0020] Each color is 33% the intensity of white light, since it is a component of white light. Additionally, each color is allocated — the total frame time. This can be demonstrate by the following formula:

$$\frac{1 \text{ sec}}{60 \text{ frames}} \times \frac{1 \text{ frame}}{1 \text{ rotation}} \times \frac{1 \text{ rotation}}{360^\circ} \times \frac{120^\circ}{\text{color}} = \frac{5.57 \text{ milliseconds}}{\text{color}}$$

[0021] An adapted version of this color wheel is shown in Figure 1B. A percentage of the total time slot allocated for each color is set aside for a "white" field. This is actually a clear, or unfiltered, section of the wheel. It will be referred to here as the white field. The decision as to what percentage is to be allocated to white depends on the desires and needs of each designer and system. Too much time given to white light may bleach the colors out and render the projection unacceptable. Too little white light used may not provide sufficient gain in perceived performance to justify the complication of adding a white light capability. In Figure 1B, 3% of the total color wheel area has been taken from each color, leaving 30% each for red 10, green 12, and blue 14. Therefore, 10% has been allocated to white 16. Using the same formula as above, with 108° for each color, and 36° for white, leads to 5.01 milliseconds for each color, and 1.67 milliseconds for white. This could increase the brightness as much as 25%. But each color saturation would be 10% less than before.

[0022] A third possibility would be to divide the wheel into four equal parts, 90° for each. This would result in a 50% brightness increase, but approximately 25% decrease in each color saturation. Each color would then receive 25% of a frame time, or 4.18 milliseconds.

[0023] Typically, the color wheel is synchronized to one junction between the fields at the beginning of every frame. In the case of the four-color wheel, the best results will most likely be achieved by synchronizing the wheel so white is the first color. This offers the possibility to raise each pixel up to a minimum brightness and then add color. For projection systems that are to be viewed directly by the eye, such as televisions, or movie projectors, it is possible that the order of presentation of the white light and the primary additive colors will be adjusted to achieve the most pleasing psycho-physical presentation. For other types of projections systems, such as in printing or film processing, the order

of presentation will be optimized for the media being exposed, with white appearing first in most cases to better utilize the dynamic range of the media.

**[0024]** For some systems, in which the light modulator has a small physical extent, it may be an advantage to spatially filter the colors. In systems with a small modulation area, increasing the modulation area increases the system efficiency. Spatial filtering is done by separating the color filters by device, or in the case of some spatial light modulators, by array area. One example of such an arrangement is shown in Figure 2A, which shows a modulator consisting of three rows of cells. One example of such a modulator is the deformable mirror device. The column of cell 20 on modulator 18 might be filtered to only receive red light. Columns for cells 22 and 24 may be filtered for green and blue light respectively. Cells 22, 24, and 20 would, in this case, illuminate the same spot on the projection surface.

**[0025]** The light is split by color by filters before or after the light impinges upon the modulation surface. This can be done in many ways, including making the window on the casing of the modulator red, green and blue, or using a grid of filters before the light reaches the modulator, or after the light is reflected off of the modulator.

**[0026]** Again, the problem of each row or device receiving only – the intensity of the white light arises. One solution for spatial filtering is shown in Figure 2B. In this embodiment, a fourth row has been added. This one would not be filtered. If the filters were in the casing of the modulator, this section of the glass would be clear. Now, cells 20, 22, 24 and 26 illuminate the same spot on the projection surface. The unfiltered pixel 26 would be used to up the overall intensity for the spot, and then color added with pixels 20, 22, and 24.

**[0027]** As with the temporal filtering discussed above, the video processor must determine a minimum brightness to be reached before the addition of color. The control functions are the same for the white light, whether done spatially or temporally. This is also true if the spatial filtering is done with a separate modulator device completely, as shown in Figure 3A.

**[0028]** In Figure 3A, there is a piece of glass 28, which has dichroic beam splitter filters built into it. Light beam 30 enters the glass piece 28. The light impinges upon red filter 32, which reflects the red light to modulator 18A. The blue and green components of the light remain unfiltered. The light then impinges upon filter 34, which separates the blue component and reflects it to modulator 18B. Surface 36 does not necessarily need to be a green filter, but for standardization of the three beams should reflect the green light to the modulator 18C. If the final light beam is not reflected, it would be the only one not reversed out of the three, and may require a modulator different from the first two.

**[0029]** This can be adapted relatively easily. The piece of glass 28 can be elongated, as shown in Figure 3B. Light beam 30 is received. In this case, only a percentage of the red light is filtered out. For example, we will assume the 10% of the red light remains in path 30. Only red light will be received at modulator 18A, but some red light will remain with the blue and green components. This is repeated for blue at filter 34, leaving 10% in path 30. Filter 38 is inserted between the reflective surface 36, and filter 34. Filter 38 reflects 90% of the green light to modulator 18C, leaving 10% in path 30. The portion of beam 30 that remains after passing through the filter 38 is white light that is 10% of the original beam's intensity. This is reflected to modulator 18D.

**[0030]** Again, a control function is needed to determine when modulator 18D is on and when it has reflected enough white light to raise the minimum intensity to the required level. Each device in the system projects onto the same projection surfaces, with the pixels overlying each other to create the necessary colors for each part of the image. As mentioned previously, there are other ways to filter spatially with separate devices for each color, and this particular embodiment is only meant as an example.

**[0031]** There is an inherent trade-off in this method of increasing brightness. The percentage of color saturation will be reduced to increase the brightness of the image. It is up to the designer to determine at what point he or she has received the maximum brightness possible, without detrimental decrease in color saturation. This method offers a flexible solution that can be achieved within the limitations of current light sources, while eliminating a redesign that may be necessary to use a brighter source.

**[0032]** Thus, although there has been described to this point particular embodiments for a system to enhance color projection with white light, it is not intended that such specific references be considered as limitations upon the scope of this invention except in-so-far as set forth in the following claims.

## Claims

1. A video display system having a light source, a color filter having red, green and blue segments (10, 12, 14), a spatial light modulator (18) for projecting pixels into a final colored image, a projection surface, and control means, wherein said color filter further has a clear segment (16) allowing the projection of white light thereby improving the perceived brightness of said final colored image, and said control means determines a minimum brightness level and operates said spatial light modulator (18) to achieve said minimum brightness during said clear segment (16).

2. The system of claim 1 wherein said color filter is a color wheel and said colors are sent to said spatial light modulator sequentially for temporal filtering.
3. The system of claim 1 wherein said color filter segments are on the casing window of said spatial light modulator (18).
4. A video display system having a light source, having a controller, four spatial light modulators (18A-18D) for projecting pixels into a final colored image, a projection surface, and a series of beam splitters (32, 34, 38) to divide light from said source that three of said spatial light modulators (18A-18C) receive light of a single filtered color component, said beam splitters (32, 34, 38) allowing a portion of said filtered color component to pass such that one of said spatial light modulator (18D) receives said portions which comprise white light and projects said white light onto said projection surface to increase the overall brightness of said final colored image, wherein said controller is operable to determine the amount of said white light projected by said spatial light modulator (18D) into said final colored image.

#### Patentansprüche

1. Video-Anzeigesystem mit einer Lichtquelle, einem Farbfilter mit roten, grünen und blauen Segmenten (10, 12, 14), einem räumlichen Lichtmodulator (18) zum Projizieren von Pixeln in ein fertiges Farbbild, einer Projektionsfläche und einem Steuermittel, wobei das Farbfilter ferner ein klares Segment (16) aufweist, das die Projektion von weißem Licht erlaubt, wodurch die wahrgenommene Helligkeit des fertigen Farbbildes verbessert wird, und das Steuermittel einen minimalen Helligkeitswert bestimmt und den räumlichen Lichtmodulator (18) so betätigt, daß diese minimale Helligkeit während des klaren Segments (16) erzielt wird.
2. System nach Anspruch 1, bei dem das Farbfilter ein Farbrad ist und die Farben zu dem räumlichen Lichtmodulator zur zeitlichen Filterung nacheinander geschickt werden.
3. System nach Anspruch 1, bei dem sich die Farbfiltersegmente auf dem Gehäusefenster des räumlichen Lichtmodulators (18) befinden.
4. Video-Anzeigesystem mit einer Lichtquelle, die eine Steuereinheit aufweist, vier räumlichen Lichtmodulatoren (18A-18D) zum Projizieren von Pixeln in ein fertiges Farbbild, einer Projektionsfläche und einer Reihe von Strahlteilern (32, 34, 38) zum Teilen von Licht von der Quelle, so daß drei der räumlichen Lichtmodulatoren (18A-18C) Licht von einer einzigen gefilterten Farbkomponente empfangen, wobei die Strahlteiler (32, 34, 38) einen Teil der gefilterten Farbkomponente durchlassen, so daß einer der räumlichen Lichtmodulatoren (18D) die Anteile empfängt, die weißes Licht enthalten, und dieses weiße Licht auf die Projektionsfläche projiziert, damit die Gesamthelligkeit des fertigen Farbbildes erhöht wird, wobei die Steuereinheit so betreibbar ist, daß sie den Anteil des von diesem räumlichen Lichtmodulator (18D) in das fertige Farbbild projizierten weißen Lichts bestimmt.

#### Revendications

1. Système d'affichage vidéo comportant une source de lumière, un filtre de couleurs ayant des segments (10, 12, 14) rouge, vert et bleu, un modulateur (18) de lumière spatial pour projeter des pixels pour former une image finale colorée, une surface de projection et des moyens de commande, ledit filtre de couleurs comportant en outre un segment (16) clair permettant la projection de lumière blanche, améliorant ainsi la luminosité perçue de ladite image finale colorée, et lesdits moyens de commande déterminant un niveau de luminosité minimum et commandant ledit modulateur de lumière spatial (18) pour obtenir ladite luminosité minimum durant ledit segment clair (16).
2. Système suivant la revendication 1, dans lequel ledit filtre de couleur est une roue colorée et lesdites couleurs sont envoyées audit modulateur de lumière spatial séquentiellement pour un filtrage temporel.
3. Système suivant la revendication 1, dans lequel lesdits segments du filtre de couleurs sont sur la fenêtre du boîtier dudit modulateur (18) de lumière spatial.
4. Système d'affichage vidéo comportant une source de lumière, un dispositif de commande, quatre modulateurs (18A à 18D) de lumière spatiaux pour projeter des pixels pour former une image finale colorée, une surface de

projection et une série de séparateurs (32, 34, 38) de faisceau pour diviser la lumière provenant de ladite source de telle manière que trois desdits modulateurs spatiaux de lumière (18A-18C) reçoivent de la lumière ayant une seule composante de couleur filtrée, lesdits séparateurs de faisceau (32, 34, 38) permettant à une partie de ladite composante colorée filtrée de passer, de telle sorte que l'un desdits modulateurs (18D) spatiaux de lumière reçoive lesdites parties comprenant de la lumière blanche et projette ladite lumière blanche sur la surface de projection pour augmenter la luminosité globale de l'image colorée finale, ledit dispositif de commande pouvant être commandé pour déterminer la quantité de ladite lumière blanche projetée par ledit modulateur spatial de lumière (18D) dans l'image finale colorée.

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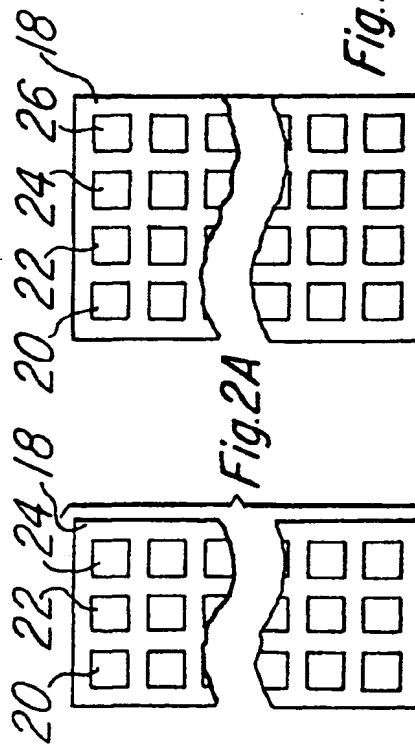
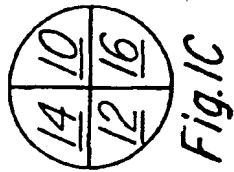
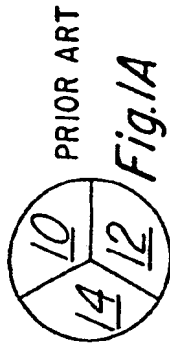
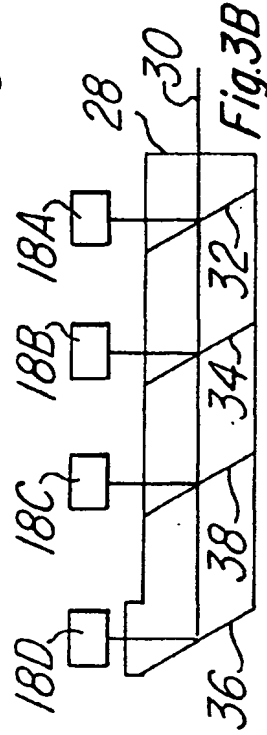
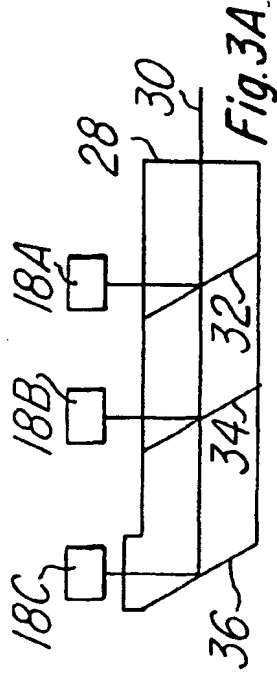


Fig. 2B



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